Great Lakes Binational Toxics Strategy

Mercury Meeting

Preliminary Evaluation of Mercury Amalgam in Dental Office Wastewater

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Objectives

1. Conduct a scientific assessment of the effects of dental amalgam discharges on the levels of methylmercury (MeHg) in the environment and

2. Evaluate the cost effectiveness of reductions in dental amalgam discharges beyond those achieved by dental Best Management Practices (BMPs).

Best Management Practices (BMPs)

- Use of pre-encapsulated amalgam
- Use of chair side traps;
- Use of vacuum filters;
- Inspection and cleaning of traps;
- Use a commercial service to dispose/recycle material from trap/vacuum filter;
- Bulk mercury collection programs.

Overview of Scientific Assessment

- **Mass balance:** The amount of Hg discharged by dentists cannot exceed that used or generated from removal of amalgams, less that captured by BMPs.
- **Systems analysis:** Interrelation of all elements – from dental office to receiving waters. Source → Capture → Bioavailability.
- **Industry-wide evaluation:** Necessary to compare cost-effectiveness with USEPA regulatory impact analyses.
- Provides a framework for estimating the fate of Hg in dental amalgam using a variety of existing data as "checks."
- Avoids the inaccuracies associated with attempting to identify the Hg content of a "typical" dental wastewater sample.

Elements of Scientific Assessment: Hg Source

- Size and characteristics of the dental community:
  - Used detailed ADA and municipal survey data to characterize:
    - The number of general dentists and specialists industry-wide.
    - The typical operating schedule of a general dentist.
    - The types of dental offices (i.e., solo vs. nonsolo dentists).

- Amount of Hg "used" by the dental community:
  - Study and vendor data to identify the Hg content of amalgams.
  - Estimated the amount of Hg triturated for placement from annual procedure rates industry-wide.
  - Checked with government estimates of Hg purchased by dentists.

- Amount of Hg discharged to dental clinic wastewater systems:
  - Used a variety of surveys to identify the rate of amalgam placements and removals, noting the decreased use in recent years.
  - Utilized technical literature on the amount of Hg released per procedure.

Elements of Scientific Assessment: Hg Capture

- Amalgam capture efficiency using BMPs (i.e., chair-side traps and vacuum filters) at clinics (~78%):
  - Evaluated results of studies of capture efficiencies.
  - Used amalgam particle size distribution data (e.g., ISO, Drummond, Cailas) to check measured data.

- The capture of Hg in POTWs (~92%):
  - Captured in POTW grit chambers → grit solids.
  - Captured in POTW clarifiers → biosolids (sludge).
  - Discharged in POTW effluent → receiving waters.

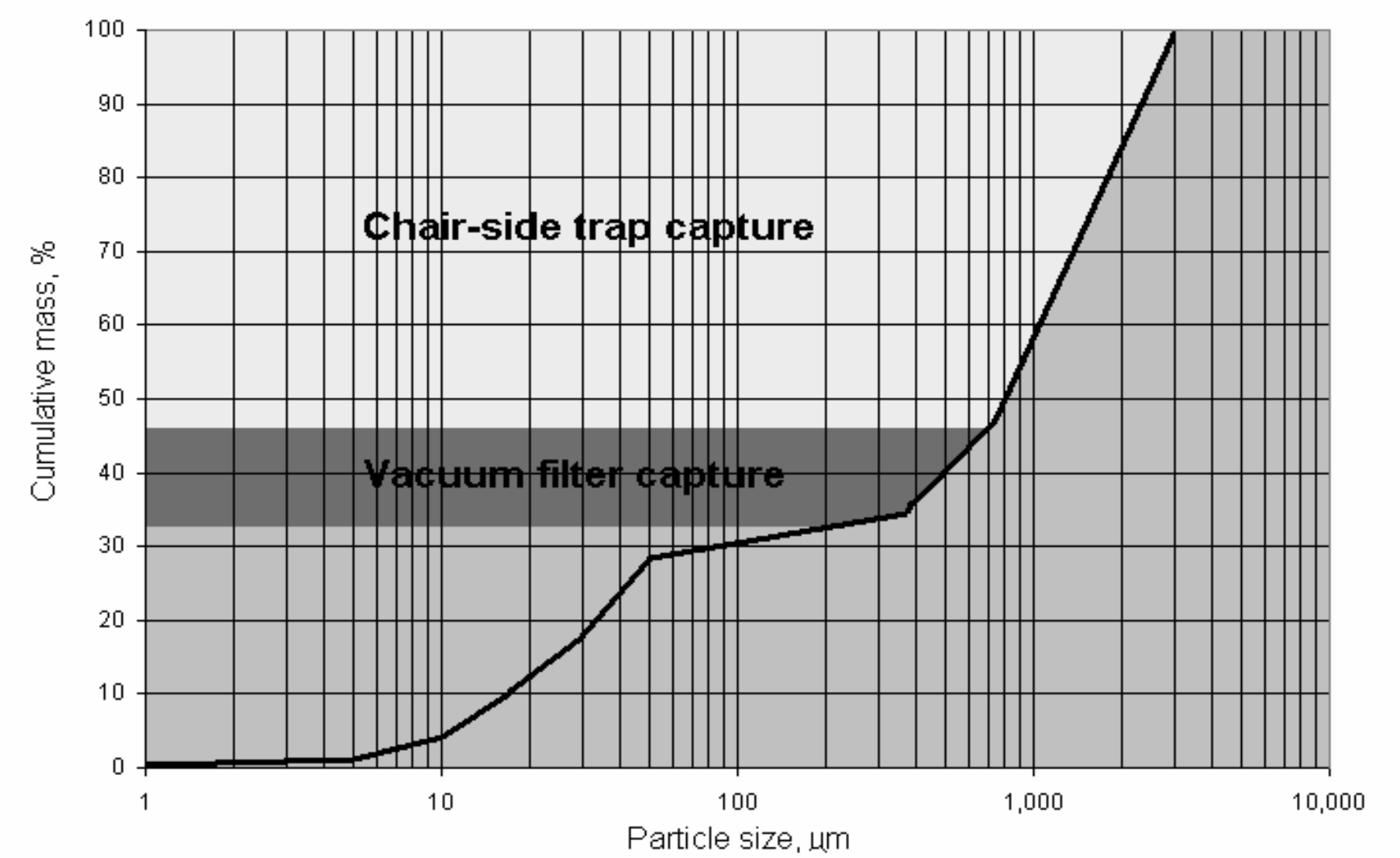
- Fate of Hg removed by dental BMPs and POTWs:
  - Mostly recycled, land-applied (in POTW sludge), or landfilled.

Hg Capture: Dental BMPs

- Chair-side traps (700 μm):
  - **Naleway 1994**. "Approximately **75%** of the amalgam particulate generated in the dental office is larger than 700 μm."
  - **Drummond et al. 1995**. During sampling, chair-side traps captured **60%** of amalgam particles.
  - **Barron 2001**. Estimated chair-side trap capture at **60%**.
  - **Seattle Metro 1993**. Estimated chair-side trap capture at **75%**.

- Vacuum filters (210 to 420 μm):
  - **Metropolitan Council Environmental Services (MCES) 2001**. Samples indicated that vacuum filters captured **42%** of amalgam.
  - **Naleway 1994**. "Approximately **50%** of the particles which pass the 700 μm screen on the dental chair are greater than 210 μm."
  - **Batchu et al. 1995**. Evaluated amalgam particle sizes and determined that **25% to 42%** were smaller than 700 μm, but greater than the pore sizes of 20- and 40-mesh vacuum filters.

Comparison: ISO Theoretical BMP Capture



Source: International Organization for Standardization (ISO) 1999.

Hg Capture: POTWs

- Association of Metropolitan Sewerage Agencies (AMSA):
  - Evaluated mercury capture at 15 plants serving communities of 15,000 to 2.5 million people throughout the US and identified mercury capture efficiencies ranging from **96 to 99%**
- California Department of Toxic Substances Control (DTSC).
  - "POTWs typically remove **90%** of the mercury from their effluents."
  - For state-wide study of mercury releases in California, DTSC has estimated POTW mercury discharges by applying **90%** capture.
- East Bay Municipal Utility District – San Francisco.
  - Based on detailed mercury sampling at 17 Bay Area POTWs, reported, "with an influent-to-effluent treatment efficiency of **>90%**, secondary wastewater treatment is a highly effective means for removing mercury."

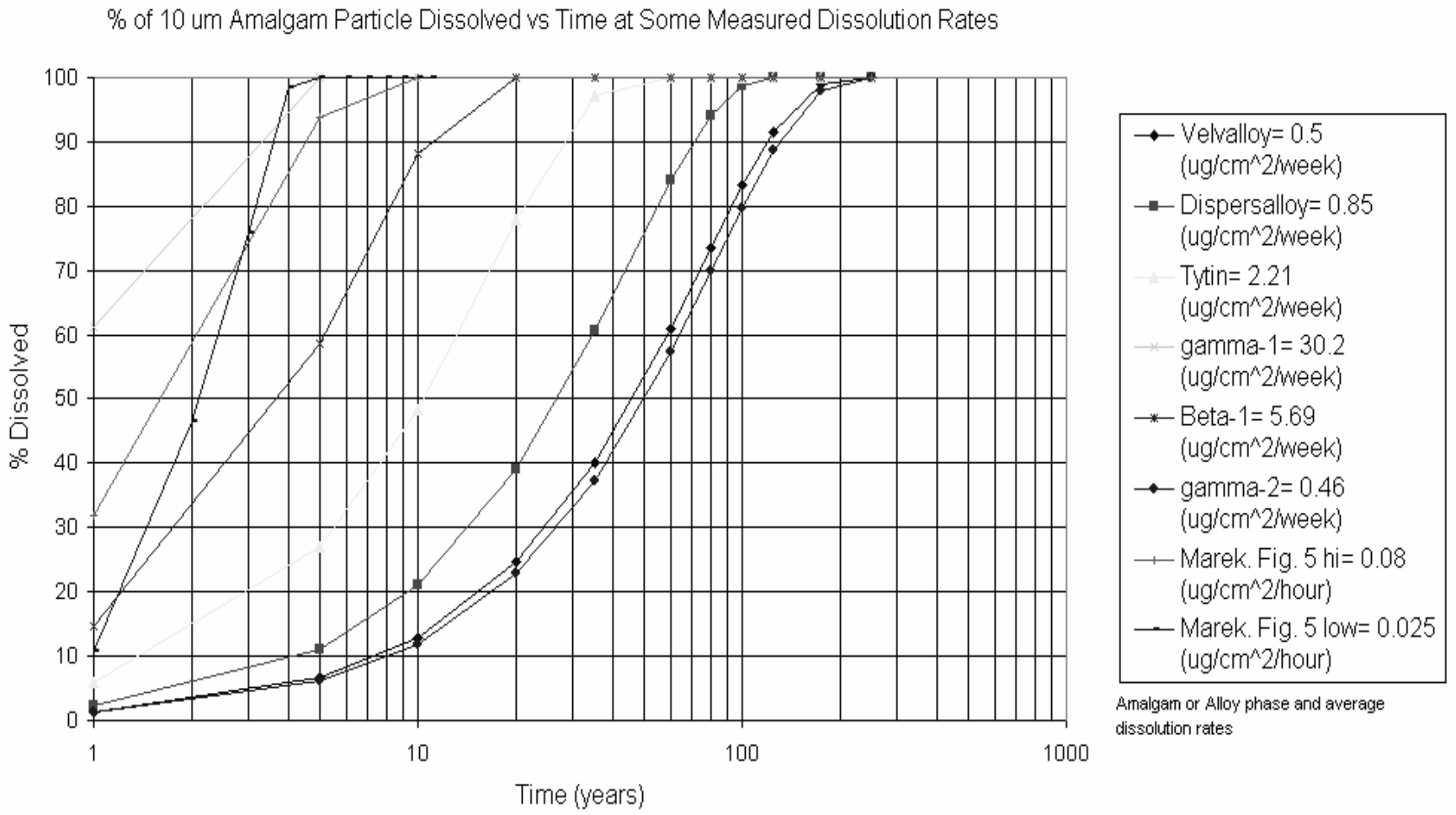
Hg Capture: POTWs (continued)

- Balogh and Liang 1995.
  - Based on a 9-week study of Metro Plant in St. Paul, MN, determined that “the average mercury removal across the entire plant was approximately **96%**.
- Balogh and Johnson 1998.
  - Based on study of mercury mass loadings for major process streams at two small POTWs in the Minneapolis-St.Paul, MN., reported that, “both plants achieved excellent (**>98%**) Hg removal across the treatment process, resulting in minimal discharges to receiving waters.”
- Theoretical considerations:
  - Naleway 1994. Based on studies of amalgam particles, concluded that, “about **90%** of the particulate will settle out of solution if left undisturbed within **1-2 hours**.”
  - Metcalf and Eddy 1991. The typical design detention time for primary sedimentation tanks at POTWs is **2.0 hours**.

Elements of Scientific Assessment: Bioavailability

- The final step – How much dental-related Hg that reaches surface waters contributes to MeHg levels?
- Primary pathways for dental-related Hg to surface waters:
  - Hg in amalgam discharged in POTW effluent.
  - Hg in amalgam incinerated in POTW biosolids.
- Hg in amalgam that is incinerated in biosolids will be largely bioavailable – emitted as gaseous elemental Hg.
- Studies indicate that the Hg in amalgam discharged in POTW effluent is largely not bioavailable, but study periods may not be representative of long-term environmental exposure.
- Conservatively assumed half of the Hg in amalgam discharged in POTW effluent will be methylated.

Hg Dissolution from Amalgam Particles

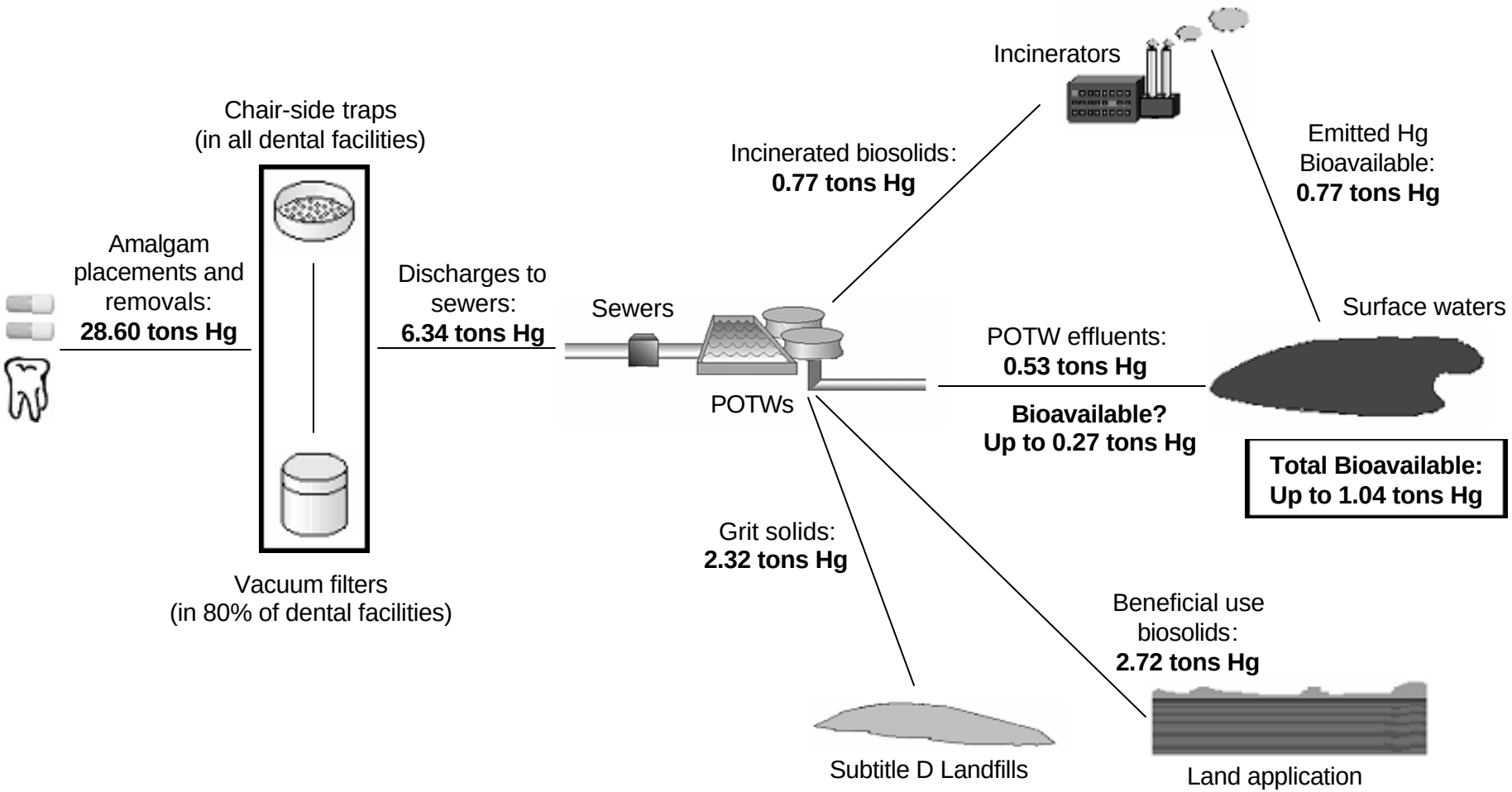


Sources: Okabe et al. 1987 and Marek 1990.

Results of Scientific Assessment

Amount purchased:		~ 31 tons
Hg discharge to clinic wastewater systems:		
– Amalgam placements:		2.24 tons
– Amalgam removals:		26.36 tons
	Total:	28.60 tons
Hg captured by dental BMPs (~78%):		22.26 tons
Hg discharged to sewer system:		6.34 tons
Hg captured by POTW (~92%)		5.81 tons
→ Hg captured in POTW grit chamber solids:		2.32 tons
→ Hg captured in POTW biosolids (sludge):		3.49 tons
Hg discharged in POTW effluent:		0.53 tons
Bioavailable Hg that *may be* methylated:		
Bioavailable Hg from POTW effluent:		up to 0.27 tons
Bioavailable Hg from incinerated biosolids (22%):		0.77 tons
	Total:	**up to 1.04 tons**

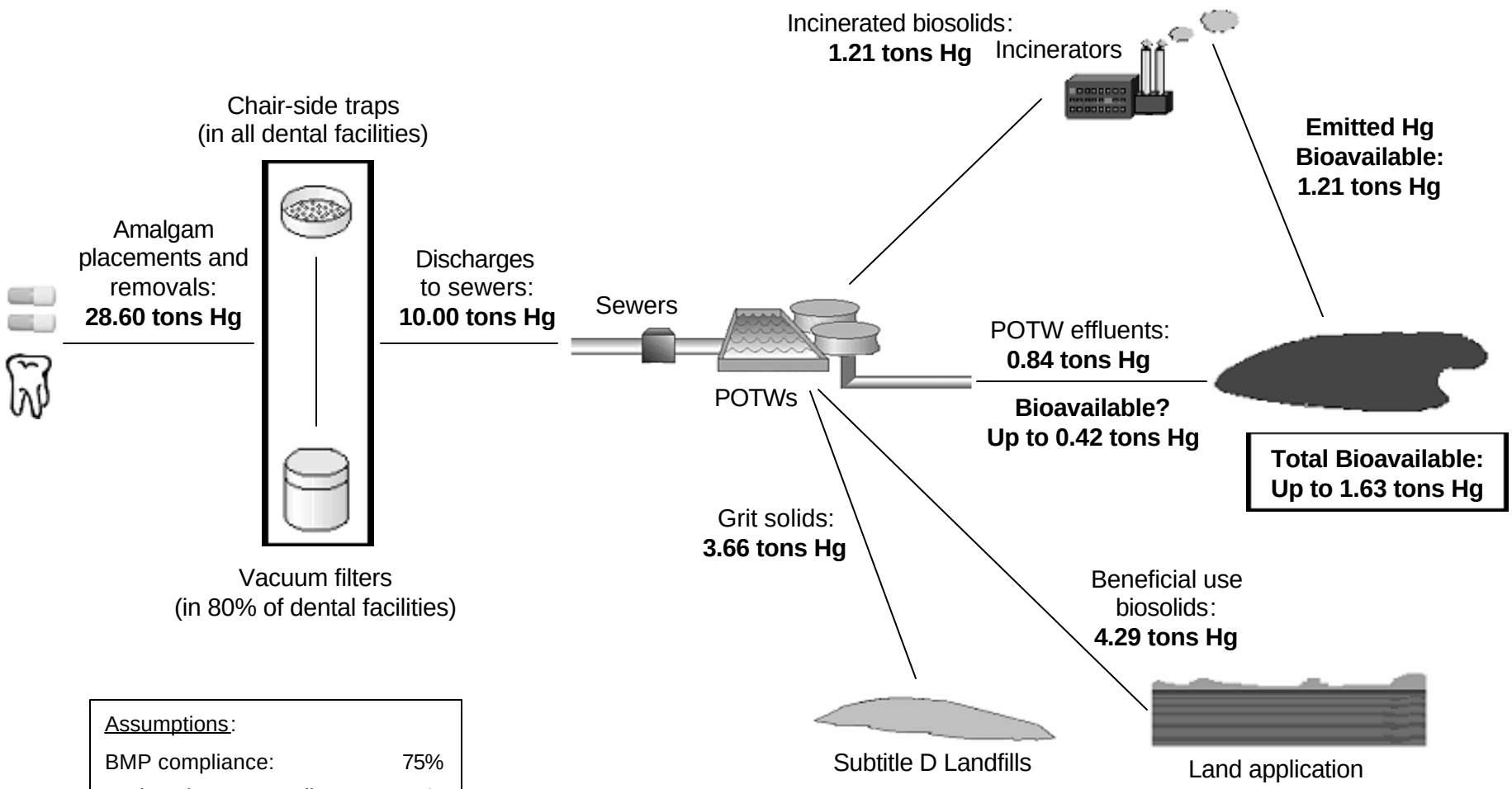
Results of Scientific Assessment (note: this represents use of BMPs)



Sensitivity Analysis: Implementation of BMPs

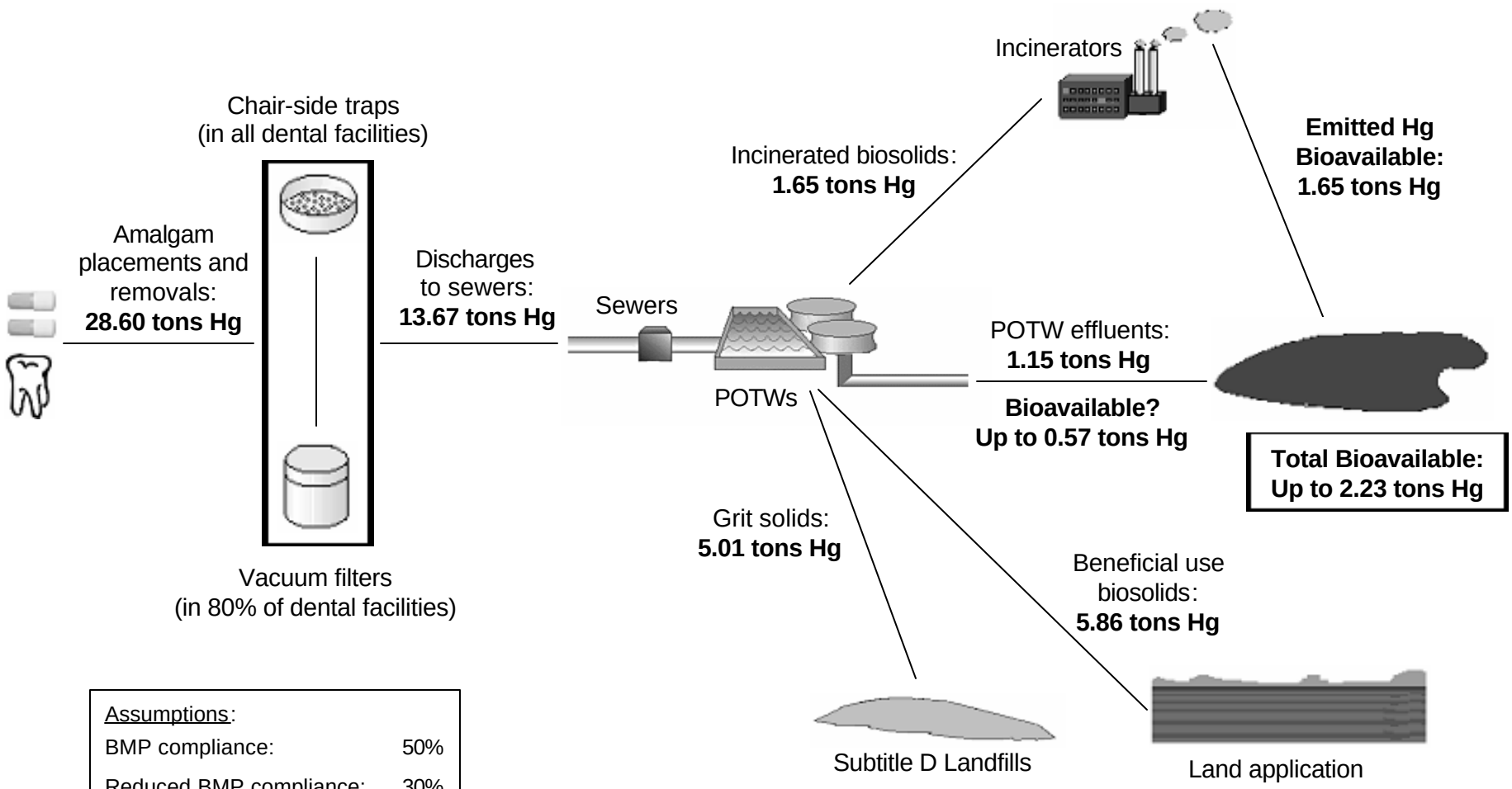
- Do all dentists follow BMPs?
- Scenario 1 – Moderate Use of BMPs:
  - 10% of dentists do not use BMPS (no trap, no filter).
  - 15% of dentists do not maintain their traps and filters, resulting in a capture efficiency for both that is one-half the optimal efficiency.
  - 75% of dentists implement BMPs in the recommended manner.
  - **65%** overall efficiency for this scenario.
- Scenario 2 – Limited Use of BMPs:
  - 20% of dentists do not use BMPS (no trap, no filter).
  - 30% of dentists do not maintain their traps and filters, resulting in a capture efficiency for both that is one-half the optimal efficiency.
  - 50% of dentists implement BMPs in the recommended manner.
  - **53%** overall efficiency for this scenario.

Sensitivity Analysis: Scenario 1 – Moderate BMP Use



Assumptions:	
BMP compliance:	75%
Reduced BMP compliance:	15%
Reduction in BMP efficiency :	50%
No BMPs (0% capture):	10%

Sensitivity Analysis: Scenario 2 – Limited BMP Use



Assumptions:	
BMP compliance:	50%
Reduced BMP compliance:	30%
Reduction in BMP efficiency:	50%
No BMPs (0% capture):	20%

Amalgam Separator Capture Efficiency

- The additional capture efficiency of an amalgam separator will vary depending upon the capture efficiencies of the dental BMPs preceding it (inverse relationship).

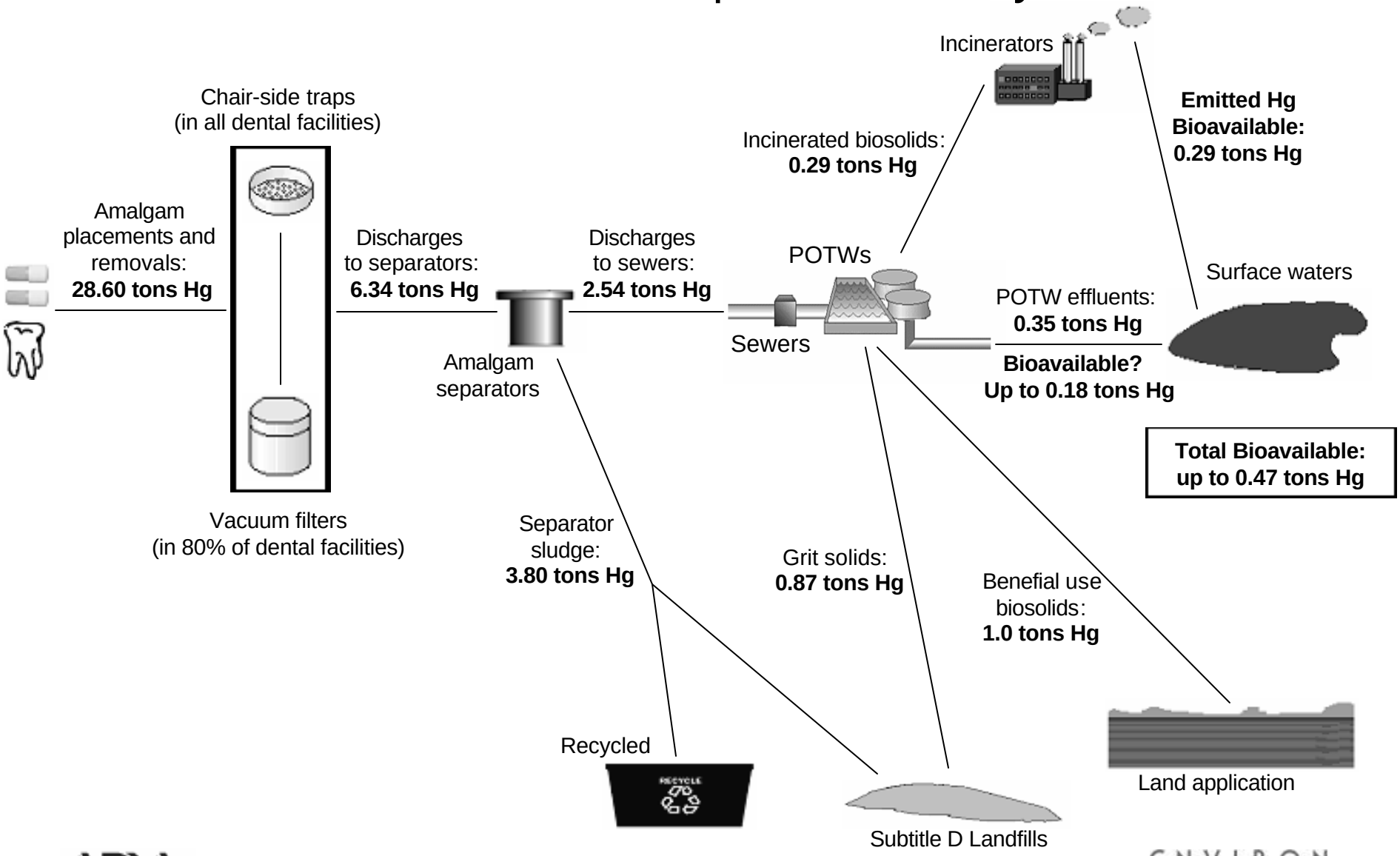
- More than half of the sample used in the ISO test (**up to 3.15 mm**) would be captured by a chair-side trap (**0.7 mm**) and vacuum filter (**0.2 – 0.4 mm**).

- Theoretical analyses and sampling data indicate that separator capture may range from about **60% to 95%** based on various scenarios:

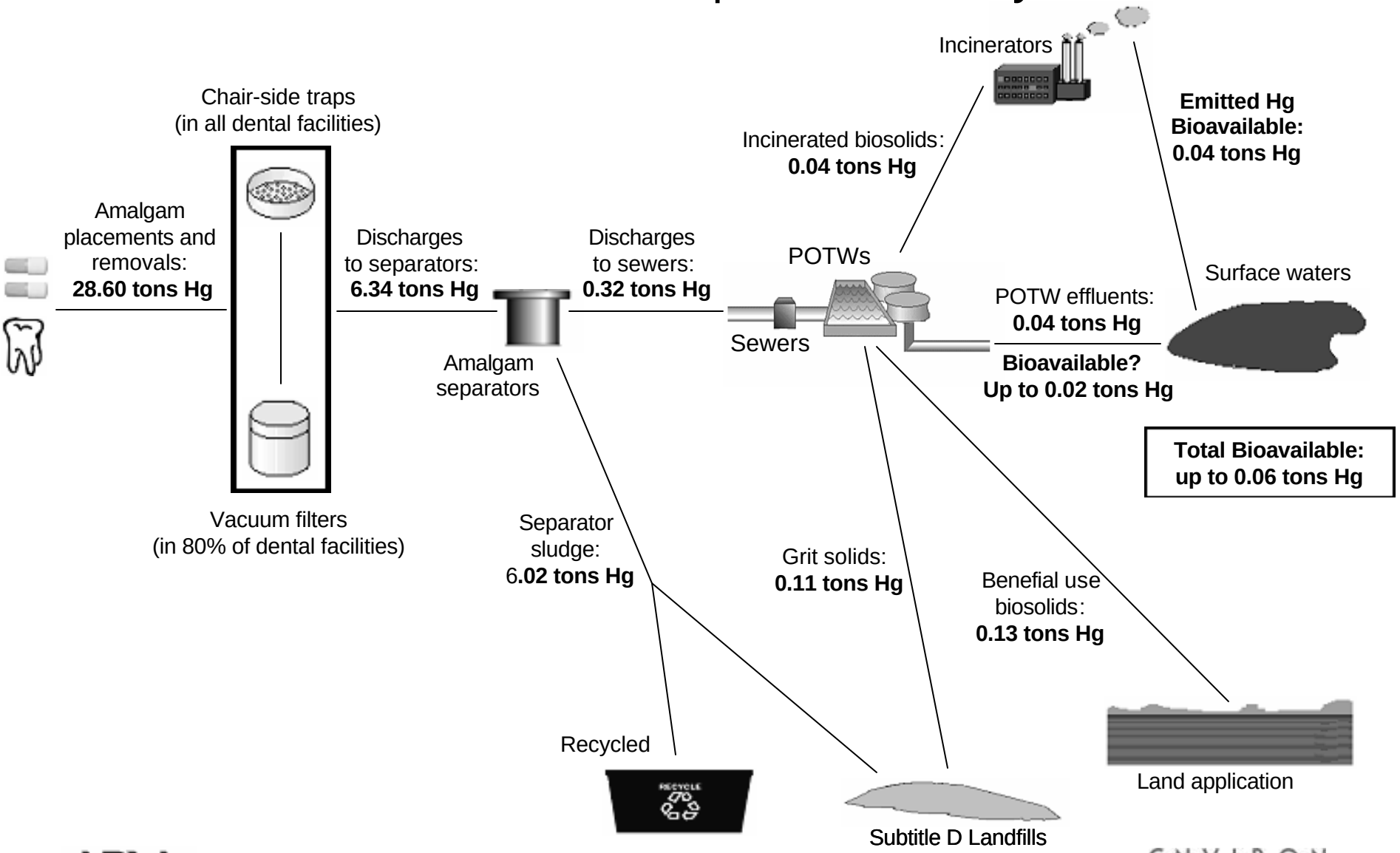
  – As low as approximately **60%** if a vacuum filter is present (remember that 80% of offices have vacuum filters).

  – As high as approximately **95%** if only a chair-side trap is present or the vacuum filter is not working correctly.
  (this would only represent 20% of dental facilities).

Hg Reduction with Amalgam Separators: 60% Additional Capture Efficiency



Hg Reduction with Amalgam Separators: 95% Additional Capture Efficiency



Net result: Range of Reduction of Bioavailable Hg Due to Use of Separators at 60% and 95%

Reduction of emitted bioavailable Hg:
0.48 tons to 0.73 tons

Surface waters

Reduction of effluent bioavailable Hg:
0.09 tons to 0.24 tons

Total reduction of bioavailable Hg:
0.57 tons to 0.97 tons

Elements of Cost-Effectiveness Analysis: Costs

- Evaluation of the direct costs of amalgam separators:
  - Vendor quotes and estimated sludge generation rates.
  - Results of ADA 2002, MCES 2001, and Palo Alto 2000 studies.
- Costs considered in this analysis:
  - Purchase and installation costs.
  - Annual operations and maintenance costs, including sludge disposal.
- Combine with amount of reduction to estimate the unit cost of reducing bioavailable dental-related Hg using separators.
- Note: A formal USEPA regulatory impact analysis would likely include additional costs, including the cost of regulation (e.g., the cost of understanding the regulatory scheme), and societal costs (e.g., increase in dental prices, office closings).

Elements of Cost-Effectiveness Analysis: Hg Reduction

- Discharge of bioavailable Hg using BMPs.

vs.

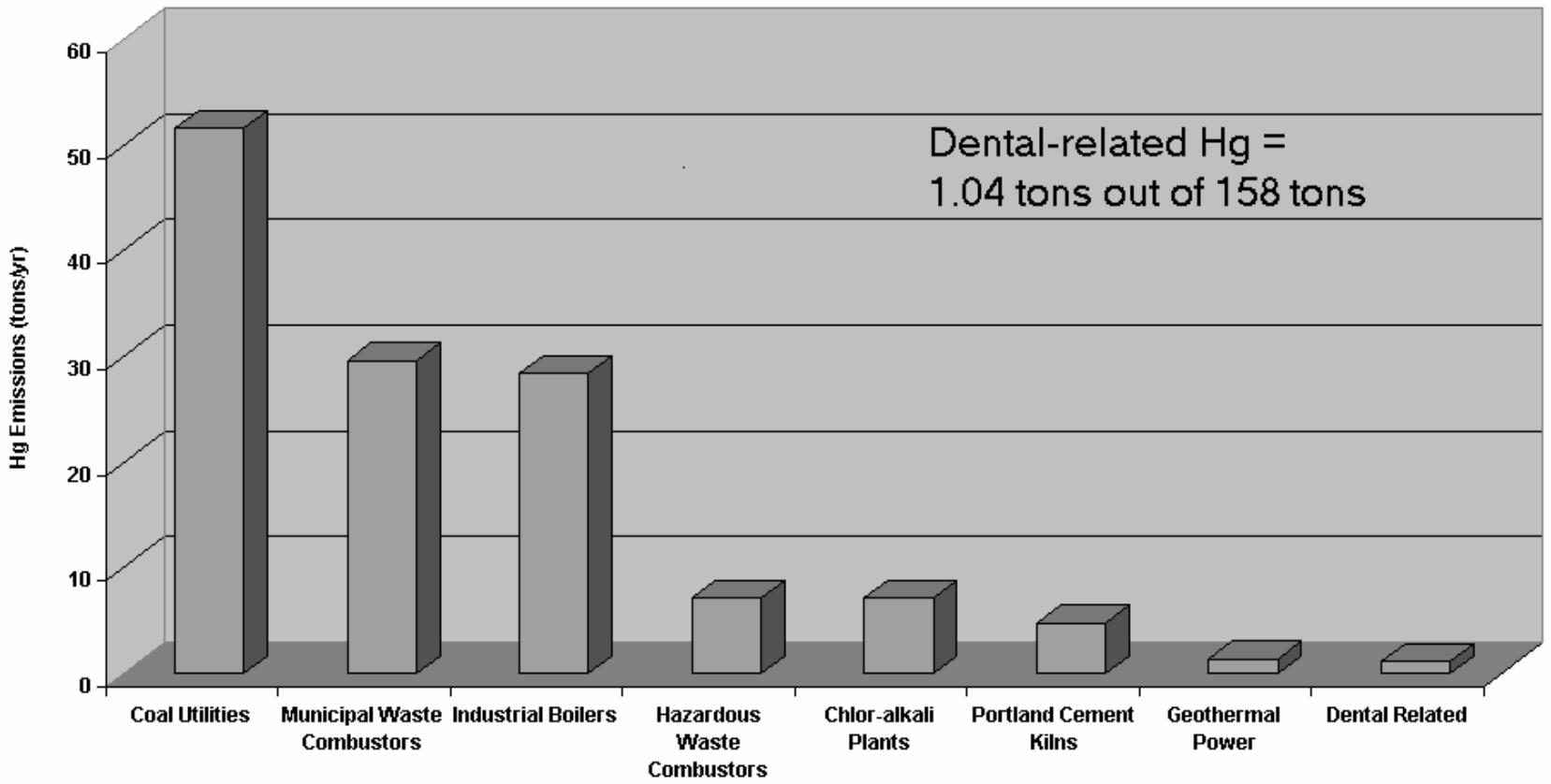
- Discharge of bioavailable Hg with amalgam separators.

- Evaluated cost-effectiveness over the range of additional separator capture efficiencies discussed:
  - 60% capture efficiency – **reduction of 0.57 tons.**
  - 95% capture efficiency – **reduction of 0.97 tons.**

Results of Cost-Effectiveness Analysis

- The use of amalgam separators will reduce potentially bioavailable dental-related Hg industry-wide by approximately **0.57 to 0.97 tons**.
- Installation and purchase of separators at an estimated 110,000 to 133,000 clinics will require $111 million to $266 million industry-wide.
- The operation and maintenance of these amalgam separators will require $78 million to $133 million per year.
- Conservatively assuming a separator has a useful life of 10 years, the combined annual cost is $89 million to $160 million per year.
- The annual cost of reducing one ton of potentially bioavailable Hg is **$91 million to $282 million per ton**.

Relative Significance of Dental Hg Discharges



Some Comparative Costs of Hg Reduction
(remember: $91 million to $282 million per ton)

- USEPA Great Lakes Water Quality Guidance (1995):
  - $84,000 to $518,000 per ton (USEPA considered “relatively high” but justifiable).
  - USEPA documentation states that regulatory action should not be taken to reduce Hg discharges if the cost-effectiveness exceeds $2 million per ton.
- USEPA Mercury Study Report to Congress (1997):
  - $422,000 to $9.2 million per ton for available technologies.
  - Identified from USEPA’s evaluation of Hg emission control technologies.
- Portland Cement Industry – USEPA NESHAP for Hg (1999):
  - $20 million to $50 million per ton.
  - USEPA did “not consider this [cost of reduction] justified” and opted to not require Hg control equipment in the NESHAP.
  - This cost included regulation and societal costs, which are not included in the cost-effectiveness analysis for amalgam separators.

Summary and Conclusions

- Dental BMPs and POTWs currently combine to capture Hg at high efficiencies from amalgam discharged in dental wastewater.

- The dental industry is a minor source of bioavailable Hg: **~ 1 ton**
  - This contribution to the environment is no more than 0.7% of total, and is likely to be considerably less.

- Amalgam separators will further reduce bioavailable Hg by **0.57 to 0.97 tons**.
  - There will be no toxicologically meaningful reduction in the amount of MeHg in the environment if separators are universally required.

- The annual cost to the dental industry of reducing one ton of potentially bioavailable Hg is about **$91 million to $282 million**.

Summary and Conclusions

- The cost to the dental industry to reduce Hg discharges using amalgam separators greatly eclipses the costs of reducing Hg for other industries and sources.

- The administrative transaction cost to municipalities, state and federal regulators and dentists to require the use of separators and obtain compliance will be substantial, probably more than the cost of installing the separators.

- The administrative transaction costs to all parties will not end with the installation of the separators – Hg discharges or ambient levels may still exceed standards.